



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification <sup>6</sup> : <b>B44F 1/12, B32B 5/16, 31/12, B42D 15/10, 101/00, 209/00, 211/00, 217/00, 223/00, 225/00</b></p>	<p><b>A1</b></p>	<p>(11) International Publication Number: <b>WO 00/18591</b></p> <p>(43) International Publication Date: 6 April 2000 (06.04.00)</p>
<p>(21) International Application Number: PCT/AU99/00830</p> <p>(22) International Filing Date: 28 September 1999 (28.09.99)</p> <p>(30) Priority Data: PP 6244 29 September 1998 (29.09.98) AU</p> <p>(71) Applicant (for all designated States except US): SECURENCY PTY LTD. [AU/AU]; Hume Highway, Craigieburn, VIC 3064 (AU).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): ZIENTEK, Paul [AU/AU]; 546 Station Street, North Carlton, VIC 3054 (AU). WILSON, Gerard, Joseph [IE/AU]; Unit 13/79 Oxford Street, Collingwood, VIC 3066 (AU).</p> <p>(74) Agent: CARTER SMITH &amp; BEADLE; Qantas House, 2 Railway Parade, Camberwell, VIC 3124 (AU).</p>		<p>(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> With international search report.</p>
<p>(54) Title: SECURITY DOCUMENT INCLUDING A NANOPARTICLE-BASED AUTHENTICATION DEVICE</p> <div data-bbox="321 1150 1318 1528" data-label="Image"> </div> <p>(57) Abstract</p> <p>A security document (1) comprising a sheet like substrate (2) having one or more layers containing particles for forming an authentication device (10) in a first location on the security document (1), the particles having at least a first dimension in the range 1 to 200 nanometers. Various methods of producing a security document and a method of producing a security feature are also disclosed.</p>		

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

## SECURITY DOCUMENT INCLUDING A NANOPARTICLE-BASED AUTHENTICATION DEVICE

The present invention relates to security documents such as banknotes,  
5 credit cards and other documents of value, and is particularly concerned with  
providing a security document with an authentication device for verifying the  
authenticity of the security document. The invention is also concerned with a  
method of producing such security documents.

The counterfeiting of currency, stocks, bonds, credit cards and other  
10 valuable documents essential to conduct business and financial activities is a  
continuing serious problem. The widespread availability of high quality imaging  
systems and the increasing technological sophistication of counterfeiters increases  
the difficulty of combatting all forms of counterfeiting.

Currently, considerable resources are devoted to the development of  
15 devices for incorporation into a security document which can be detected to  
validate the document's authenticity. Holograms, opaque print strips and  
microprinting are examples of such devices, and their effectiveness depends upon  
the difficulties involved in counterfeiting them.

An aim of the present invention is to provide an authentication device for  
20 incorporation in a security document which acts to effectively circumvent  
counterfeiting of the security document.

With that in mind, one aspect of the present invention provides a security  
document comprising a sheet-like substrate having one or more layers containing  
particles for forming an authentication device in a first location on the security  
25 document, the particles having at least a first dimension in the range of 1 to 200  
nanometers.

The particles may be substantially spherical. In another embodiment, the  
particles may be elongated. In a third embodiment, the particles may be a series  
of spherical particles concatenated together, in the form of "beads-over-string". In  
30 the case of elongated particles, at least a first group of the particles may be aligned  
so that their longitudinal axes are substantially parallel. The longitudinal axis of

the first group of particles may extend in a first direction at an angle to the plane of the security document.

A second group of the particles may be aligned so that their longitudinal axes extends in a second direction at an angle to the plane of the security document, the first and second directions being non-co-linear.

The first group of particles may be arranged so as to polarize incident light waves. In one embodiment, the security document may include, at a second location, a polarizing analyzer for interaction with the light polarizer at the first location.

The particles may be laterally spaced from each other so as to form at least a first diffraction grating at the first location. The lateral spacing may be achieved by coating each particle with a transparent material of controllable thickness, such as silica.

The particles may be selected from materials which reflect incident light waves. Alternatively, the particles may act to fluoresce or luminesce light waves therefrom.

In a further embodiment of the invention, the particles may be selected from materials to reflect incident sound or acoustic waves or from materials that absorb energy (light or sound) and subsequently re-emit this energy acoustically.

The particles may be made from material which is orientable in an electric, magnetic or electromagnetic field. In this way, alignment of the particles may be affected by selective application of that specified field to at least the first group of particles.

Another aspect of the present invention provides a method of producing a security document, comprising the steps of:

(a) forming a sheet-like substrate having one or more layers containing particles for forming an authentication device at a first location on the security document, the particles having at least a first dimension in the range of 1 to 200 nanometers,

(b) melting at least a portion of the first layer such that the particles can orient under the influence of external field,

- (c) applying the external field so as to orient the particles,
- (d) allowing the first layer to cool so as to fix the orientation of the particles.

The external field may be for example an electric, magnetic,  
5 electromagnetic, mechanically induced stress field.

A further aspect of the present invention provides a method for producing a security feature for use in a security document, comprising the steps of:

- (a) forming a sheet-like substrate,
- (b) producing pores in an outer layer of the substrate at regular  
10 intervals, the pores having a pre-determined alignment with each other, and
- (c) depositing particles in the pores, the particles having at least a first dimension in the range of 1 to 200 nanometers

The particles may be deposited by an electro-deposition process. The outer layer may be made from a polymer-based material.

15 The pores may be formed by orienting the substrate so that its plane is at an angle to the beam of an energy source, exposing the substrate to the energy source beams such that pores are formed in an outer layer of the substrate, the longitudinal axis of the pores being substantially aligned with the direction of the energy source beam.

20 Yet another aspect of the present invention provides a method of producing a security document, comprising the steps of:

- (a) forming a sheet-like substrate,
- (b) placing particles for forming an authentication device on a transfer film, the particles having at least a first dimension in the range of 1 to 200  
25 nanometers, and

- (c) using a die to cause the transfer film to press the particles into the substrate.

The die may be heated so that an outer layer of the substrate is melted thereby to facilitate the transfer of the particles from the transfer film into the  
30 substrate.

The die may be an embossing die and may be adapted to form a saw-tooth or like profile in the surface of the substrate, in order to enable the positioning of the particles in the outer layer of the substrate, whereby the longitudinal axis of the particles is at an angle to the plane of the security document.

5 A further aspect of the invention provides a method of producing a security document, comprising the steps of:

- (a) forming a sheet-like substrate,
- (b) coating at least a first outer surface of the substrate with a layer containing spherical particles having a diameter in the range of 1 to 200  
10 nanometers,
- (c) heating at least one or more selected portions of the layer to allow the spherical particles to self-assemble into a concatenated series within said at least one of more selected areas.

In order that the present invention may be more readily understood, various  
15 embodiments thereof will be now described, by way of example only, with reference to the accompanying drawings.

In the drawings:

Figure 1 is a cross-sectional side view of a first embodiment of a security document according to the present invention;

20 Figure 2 is a cross-sectional side view of a second embodiment of a security document according to the present invention;

Figure 3 is a perspective view of the security document of Figure 2;

Figure 4 is a diagram showing the spectral absorption of particles for use in a security document according to the present invention;

25 Figure 5 is a schematic diagram showing the orientation of the particles used in the security document of Figure 2;

Figures 6 and 7 are cross-sectional side views of a third embodiment of a security document according to the present invention;

Figures 8 and 9 are schematic representations of portions of the security  
30 document of Figures 6 and 7;

Figure 10 is a schematic plan view showing a lined particle suitable for use in a security document according to the present invention;

Figure 11 is a schematic plan view of particles encapsulated in a clear transparent material for use in a security document according to the present invention;

Figure 12 is a cross-sectional side view of a fourth embodiment of a security document according to the present invention;

Figure 13 is a cross-sectional side view of a fifth embodiment of a security document according to the present invention;

Figure 14 is a schematic diagram showing a first method of locating particles in a substrate so as to form a security document according to the present invention; and

Figure 15 is a schematic diagram showing a second method for enabling the location of particles in a substrate so as to form a security document according to the present invention.

Referring now to Figure 1, there is shown generally a banknote 1 comprising a sheet-like substrate 2 preferably of plastics material and having first and second opposing surfaces 3 and 4. Various indicia may be formed on at least one of the first and second opposing surfaces 7 and 8, such as drawings, writing and other designs well known to manufacturers and users of banknotes.

The substrate is preferably a composite made from at least biaxially oriented polymeric film 5 which is coated on both sides with an opacifying pigmentary coating 6 and 7 comprising a major portion of pigment in a minor portion of cross-linked polymeric binder. A transparent protective coating (not shown) is preferably applied to both sides of the banknote 1 in order to protect it from wear. The transparent protective layer may include silica or like particles so as to improve the adherence of the banknote 1 when handled by a user.

The substrate 2 includes copolymer outer coatings 8 and 9 of the biaxially oriented polymeric film 5. An authentication device 10 is formed at a first location on the banknote 1 by the inclusion of nanoparticles in at least a portion of the copolymer outer coating 8. These nanoparticles have at least a first dimension

in the range of 1 to 200 nanometers, and, when included in a security document, provide a number of features suitable for use as an authentication device, as will be explained below.

The opacification layer 6 of the banknote 1 does not extend over the entire surface 3 of the substrate 2, but leaves a portion of the substrate 2 uncovered in the vicinity of the authentication device 10. This embodiment of the authentication device 10 takes advantage of particular optical effects of the nanoparticles included in the copolymer outer layer 8 or otherwise visible by a user. In this example, nanoparticles made from gold or other material which scatters and absorbs incident light waves are used in the authentication device 10. Nanoparticles of this type have been observed to exhibit isotropic absorption of incident light waves, their absorption spectrum being a function of both their aspect ratio, that is to say the ratio of their length to width, and their orientation. The absorption spectra for such nanoparticles in solution each having the same width of 10 nanometers but having different lengths is shown in Figure 4. It has been observed that the short-axis polarized band, indicated by the reference "S" does not change in position, whereas the long-axis polarized band, indicated by the reference "L", shifts to a longer wavelength as the length of the nanoparticles increases. In the simplest case, nanoparticles of a spherical shape may be used in the authentication device 10. Such gold nanospheres have been observed to exhibit a colour shift in reflection as a function of the viewing angle  $\alpha$ . Such an authentication device will have a typical "green-golden" colour when viewed under specular reflection and appears red-crimson when viewed in diffuse reflectance. The actual "red-crimson" colour which is viewed in diffuse reflectance will depend upon the actual size of the nanosphere and on the thickness of any coating on it.

Alternatively, nanorods, nanoellipsoids or other elongated nanoparticles may be used in order to alter the colour observed by a user both under specular reflection and by diffuse reflectance of light on the surface of the authentication device 10.



The same nanoparticles have also been observed to exhibit a colour shift when viewed in transmission versus reflection. Figure 2 shows a banknote 20 which takes advantage of this property. The same substrate 2, including the biaxially oriented polymeric film 5 and copolymer outer coatings 8 and 9 are used.

5 However, the opacifying layers 6 and 7 do not entirely cover the outer surfaces 3 and 4 of the substrate, but leave open a region W enabling the transmission of light through the substrate 2. In this case, a colour difference is observed by a user depending upon whether light from a source 21 is viewed in reflection, at position 22, or in transmission, at position 23.

10 A variation in the colour observed by a user may also be achieved by the alignment of elongate nanoparticles in the authentication device 10. Alignment of at least a first group of the particles so that their longitudinal axes are substantially parallel results in not only a colour variation depending upon the angle  $\alpha$  at which the banknote 20 is tilted, but which is also dependent upon an angle  $\beta$  at which the  
15 banknote is rotated whilst being maintained in substantially the same plane.

If, as shown in Figure 5, the longitudinal axis of a first group of elongate nanoparticles are arranged to extend in a first direction at an angle to the plane of the security document, a noted colour variation depending upon the angle of rotation  $\beta$  of the banknote 20 is observed. In the example illustrated in Figure 5,  
20 the group 30 of elongate particles have their longitudinal axes extending in a first direction indicated by the arrow 31 at an angle  $\gamma$  to the plane of the security document. In such a configuration, a shift in the absorption spectrum is observed by the viewer between the positions 32 and 33.

In other embodiments of the invention, a second or further groups of  
25 particles may be aligned so that their longitudinal axes extend in a second direction, which is different from the direction indicated by the arrow 31, at an angle to the plane of the security document. In this way, various patterns may be observed by a viewer of the authentication device, the various portions of the pattern being formed by the various groups of aligned particles within the  
30 authentication device. The various parts of the authentication device will exhibit a

viewed colour difference depending upon the orientation of the banknote 20 with respect to the viewer.

Whilst the nanoparticles used in the authentication device 10 of Figures 1 to 5 are adapted to reflect incident light waves, similar optical effects may be achieved with nanoparticles which act to fluoresce or luminesce light waves therefrom.

Referring now to Figure 6, there is shown a further embodiment of the present invention in which the optical effects of the nanoparticles arise from polarization of incident light. In this figure, the banknote 40 again includes a substrate 41 including a biaxially oriented polymeric film 42 and 2 copolymer outer coatings 43 and 44. Opacifying coatings 45 and 46 are formed on the outer surfaces of the copolymer outer coatings 43 and 44. An authentication device 47 is formed at a first location on the banknote 40. In this example, elongate nanoparticles are positioned within the copolymer outer coating 43 such that their longitudinal axes are substantially parallel with the plane of the banknote 40 and are aligned in a first selected direction. In the example shown, a window X is formed through the banknote 40 in the vicinity of the authentication device 47, by leaving that portion of the transparent substrate 41 uncoated by the opacifying coatings 46 and 45. The group of aligned nanoparticles located in the copolymer outer layer 43 forming part of the authentication device 47 cover only a portion Y of the width of the window X. Because the absorption spectrum of the nanoparticles is anisotropic, it may act as efficient light polarizers. They do this by selectively absorbing the plane of polarized light at a specific wavelength, as indicated in Figure 4. In this application there is no need to orient the elongate nanoparticles at an angle relative to the viewer and the elongate nanoparticles are simply laid down with their longitudinal axes parallel to the banknote surface.

Patterns may be formed within the window X by providing a further group or groups of elongate nanoparticles having their longitudinal axes aligned along a different direction to that of the first group of nanoparticles. For example, whilst a first group of nanoparticles 48 in the copolymer outer coating 43 may be oriented along a first direction, other groups 49 and 50 of elongate nanoparticles may be

formed in the opposing copolymer outer coating 44 in areas within the boundaries of the window X, but outside the boundaries of the first group of elongate nanoparticles Y. The latent image thus formed when the banknote is viewed in transmission is invisible as all the elongate nanoparticles have their longitudinal axis normal to the viewing direction, thus producing a uniform colour.

However, when an analyzer is interposed between the latent image and the viewer, extinction occurs where the long individual axes of the elongate nanoparticles are orthogonal. Conveniently, the analyzer may be provided at a second location on the banknote 40 so that, as seen in Figure 7, the banknote 40 may be folded so as to superpose the analyzer 51 and the polarizing authentication device 47. Alternatively, the analyzer may be provided on a separate document or device. For example, 2 banknotes or other security documents including the authentication device 47 may be used to verify each other.

The analyzer 51 is formed by locating elongate nanoparticles within a window Z of the banknote 40. The elongate nanoparticles in the analyzer 51 have their longitudinal axes aligned along a direction coincident with the direction along which one or more groups of particles forming part of the authentication device are aligned.

Figure 8 provides an illustration of this. In this example, the first group of elongate nanoparticles are located in the outer copolymer layer 43 with their longitudinal axes extending in the direction indicated by the arrow 52. The groups 49, 50 of elongate nanoparticles in the copolymer outer layer 44 have their longitudinal axes extending in the direction indicated by the arrow 53. When the window 47 of the banknote is examined by a user, the latent pattern or image formed by the groups 48 to 50 of elongate nanoparticles is not visible to the user. The elongate nanoparticles in the groups 48 to 50 are so disposed in the copolymer outer layers 43, 44 so as to polarized incident light waves. The group of elongate nanoparticles in the analyzer 51 have their longitudinal axes extending in the direction indicated by the arrow 53. When the two portions of the banknote 40 are superposed, as in Figure 7, extinction of image occurs where the longitudinal axis of the elongate nanoparticles in the analyzer 51 are orthogonal with the

longitudinal axes of the elongate nanoparticles in the group 48 of nanoparticles in the polarizer 47. The resultant exposed image is referenced 54.

Figure 9 schematically illustrates the fact that the group 48 of elongate nanoparticles may be applied to one outer layer of the banknote 40, whilst the groups 49, 50 may be applied to the opposing side of the banknote 40. In other embodiments, it is to be appreciated that one or more or all groups of nanoparticles forming such a pattern may be formed in an outer layer. In other embodiments of the invention, the nanoparticles may be located in the central polymeric film 42.

Once the previously described authentication devices relied upon the absorption spectrum of nanoparticles to produce a security optical effect, authentication devices including such nanoparticles may be created which rely upon the diffraction of incident light. If elongate nanoparticles are packed as shown in Figure 10, that is to say with their longitudinal axes aligned in the same direction but where the nanoparticles are not laterally spaced, no controllable diffraction effects result. However, if the elongate nanoparticles are arranged in an authentication device so that their longitudinal axes extend in the same direction and the spacing between the nanoparticles is controlled, then an authentication device exhibiting zero order diffraction effects may be produced. One way of achieving this effect is via the encapsulation of the elongate nanoparticles in a transparent material of controllable thickness, such as silica. The grating period in this case is equal to the width of the nanoparticle plus twice the wall thickness. Varying the thickness of the coating determines the spacing between adjacent elongate nanoparticles and, consequently, the diffraction effect achieved.

A ligand with a sulphur atom at one end and a siloxal group at the other can be used to attach itself to the gold surface of the elongate nanoparticle via the sulphur atom. The distal end of the ligand is then polymerized via a sol-gel reaction to produce a glassy shell around the gold nanoparticle core. The thickness of this shell is easily controlled and so different grating periods are attainable.

Advantageously, grating structure produced according to this technique are totally shielded from their immediate environment and further more behave in the same manner as silica. This enables the convenient orientation of the elongate nanoparticles via the presence of a static electric field.

5           Although the previously described structures have included nanoparticles located in the outer layers of the substrate 2, it is of course possible to locate the nanoparticles elsewhere within the substrate. As shown in Figure 12, an authentication device based upon the optical properties and effects of nanoparticles may be created in which the nanoparticles are centrally located  
10          within the substrate 2, providing a window is located in the opacifying layer 45 or 46 for viewing of these optical effects.

          The use of acoustic or audio waves to elucidate nanoparticle size may also be used in the context of the present invention. In this case, the inclusion of nanoparticles at any convenient location within the substrate 2 results in an  
15          authentication device which does not require visual access to the location within the substrate 2 at which the nanoparticles are held. The authenticity of the security document can be verified by observation of the response to the acoustic waves and verification that the response corresponds to that of an object containing nanoparticles of the size expected to be within that security document. In this  
20          case, low concentrations of nanoparticles may be incorporated into banknote film, each denomination having different sized nanoparticles. Authentication and denomination are determined by measuring the different responses to the exciting audio frequency.

          The spectra shown in Figure 4 may be achieved without a specific  
25          orientation of the longitudinal axes of the nanoparticles. Accordingly, in authentication devices based upon this optical effect, the nanoparticles may easily be formed in the substrate 2 or subsequently located in an outer layer of the substrate by a variety of techniques. For example, the particles may be supported on a transfer foil or film and a heated die is used to press the transfer film to the  
30          outer layer of the substrate and so transfer the nanoparticles into the outer layer of the substrate.

In those embodiments of the invention where the longitudinal axes of elongate nanoparticles are required to be aligned, various alignment techniques may be used.

For example, the nanoparticles may be formed in one or more layers of the substrate, and heat applied to at least a first portion of the layer so that the nanoparticles are free to orient themselves. An external field, such as an electric, magnetic, electromagnetic, or mechanically induced stress field, may then be applied so as to orient the nanoparticles in one or more desired directions. The layer may then be allowed to cool so as to fix the orientation of the nanoparticles.

10 In another example, as shown in Figure 14, the nanoparticles may be oriented in a uniform direction on a transfer film or foil. The aligned elongate nanoparticles are then transferred onto the substrate by an embossing technique. Preferably, they are transferred from the release film, although in other embodiments the film may be perforated by the die and also transferred onto the substrate, thereby forming a protective layer of the nanoparticles. The transfer process also embosses the substrate. In this case, the die has a saw-tooth pattern and again various components of an image have their saw-tooth patterns arranged at different angles relative to each other. The profile of the die in this case is much greater than the length of the elongate nanoparticles. Techniques for achieving alignment of the elongate nanoparticles include the use of surface tension, static electricity, magnetic fields and entropic forces. In addition, stretching, the use of static or periodically changing EM fields and self-assembly may be used as ways of orienting the particles.

Alternatively, as illustrated in Figure 15, the elongate nanoparticles may be deposited into pores formed in the outer layer of the substrate. The nanoparticles may be synthesized according to this technique by anodizing the polymer outer layer of the substrate to produce uniform pores in the polymer spaced at regular intervals. The anodizing conditions determine the pore diameter and density. The material used to produce the elongate nanoparticles, such as silver or gold, may then be electrodeposited into the pores. The electrodeposition time period determines the length of the longitudinal axis of the nanoparticle in the pore.

In those embodiments of the invention where the longitudinal axis of the elongate nanoparticles is required to be at an angle to the plane of the security document, the substrate 2 may be exposed to an energy source S whilst the security document is oriented at an angle other than perpendicular to the direction  
5 of a beam from the energy source. The tracks thus left in the substrate are therefore oriented at that angle to the normal. The tracks are then able to be used directly as pores for electrodeposition or may be etched to increase their dimensions prior to electrodeposition.

In yet another example, at least a first outer surface of the substrate may be  
10 coated with a layer containing spherical nanoparticles, and heat then applied to the layer to allow the spherical nanoparticles to self assemble into a concatenated series. Heat may be applied to the layer as a whole, or to one or more selected portions of the layers. Concatenated series of nanoparticles, or "beads-on-a-string", may thus be created in each of the selected portions. The aspect ratio of  
15 the nanoparticle structures may be controlled by the temperature and duration of the heating.

It will be appreciated that various modifications and alterations may be made to the embodiments of the present invention described above without departing from the spirit or scope of the present invention.

20 The nanoparticles may be used to incorporate covert, machine readable structures into the security document of the present invention. Such structures take advantage of the spectroscopic signals that are unique to nanoparticles, and include narrow bandwidth photoluminescence, polarised photoluminescence, surface enhanced Raman effects, acoustic and photoacoustic effects, magnetic  
25 effects and the like.

It will be appreciated that a combination of nanoparticles homogeneously or otherwise distributed within one or more layers of the substrate may be used in the invention. Such a combination would allow the incorporation of multiple nanoparticle effects in a single security document.

## CLAIMS

1. A security document comprising a sheet-like substrate having one or more layers containing particles for forming an authentication device in a first location on a security document, the particles having at least a first dimension in the range of 1 to 200 nanometers.
2. A security document according to claim 1, wherein the particles are substantially spherical.
3. A security document according to claim 1, wherein the particles are elongated.
4. A security document according to claim 3, wherein at least a first group of the particles are aligned so that their longitudinal axes are substantially parallel.
5. A security document according to claim 4, wherein the longitudinal axis of the first group of particles extend in a first direction at an angle to the plane of the security document.
6. A security document according to claim 5, wherein a second group of particles are aligned so that their longitudinal axes extend in a second direction at an angle to the plane of the security document, the first and second directions being noncolinear.
7. A security document according to any one of claims 4 to 6, wherein the first group of particles are arranged so as to polarise incident light waves.
8. A security document according to claim 7, and further comprising, at a second location, a polarising analyser for interaction with the light polariser at the first location.
9. A security document according to claim 1, wherein the particles are spherical and form a series of particles concatenated together.



10. A security document according to any one of the preceding claims, wherein the particles are laterally spaced from each other so as to form at least a first defraction grating at the first location.
- 5 11. A security document according to claim 10, wherein the lateral spacing is achieved by coating each particle with a transparent material of controlable thickness, such as silica.
- 10 12. A security document according to any one of the preceding claims, wherein the particles are selected from materials which reflect incident light waves.
13. A security document according to any one of claims 1 to 11, wherein the particles act to fluoresce or luminous light waves therefrom.
- 15 14. A security document according to any one of claims 1 to 11, wherein the particles are selected from materials to reflect incident sound or acoustic waves.
- 20 15. A security document according to any one of claims 1 to 11, wherein the particles are selected from materials that absorb light or sound energy and subsequently re-emit said energy acoustically.
- 25 16. A security document according to any one of the preceding claims, wherein the particles are made from material which is orientable in an electric, magnetic or electromagnetic field.
17. A method of producing a security document, comprising the steps of:
- (a) forming a sheet-like substrate having one or more layers containing particles for forming an authentication device at a first location on the security document, the particles having at least a first dimension in the range of 1 to 200 nanometers,
  - (b) melting at least a portion of the first layer such that the particles can orient under the influence of an external field,
  - (c) applying the external field so as to orient particles,
- 30

(d) allowing the first layer to cool so as to fix the orientation of the particles.

18. A method of producing a security document, according to claim 17, wherein the external field is one of an electric, magnetic, electromagnetic or mechanically induced stress field.

19. A method for producing a security feature for use in security document, comprising the steps of:

- (a) forming a sheet-like substrate,
- 10 (b) producing pores in an outer layer of the substrate at regular intervals, the pores having a predetermined alignment with each other, and
- (c) depositing particles in the pores, the particles having at least a first mention in the range of 1 to 200 nanometers.

15 20. A method for producing a security feature according to claim 19, wherein the particles are deposited by an electrodeposition process.

21. A method for producing a security feature according to either of claims 19 or 20, wherein the outer layer is made from either a metal or polymer based material.

20

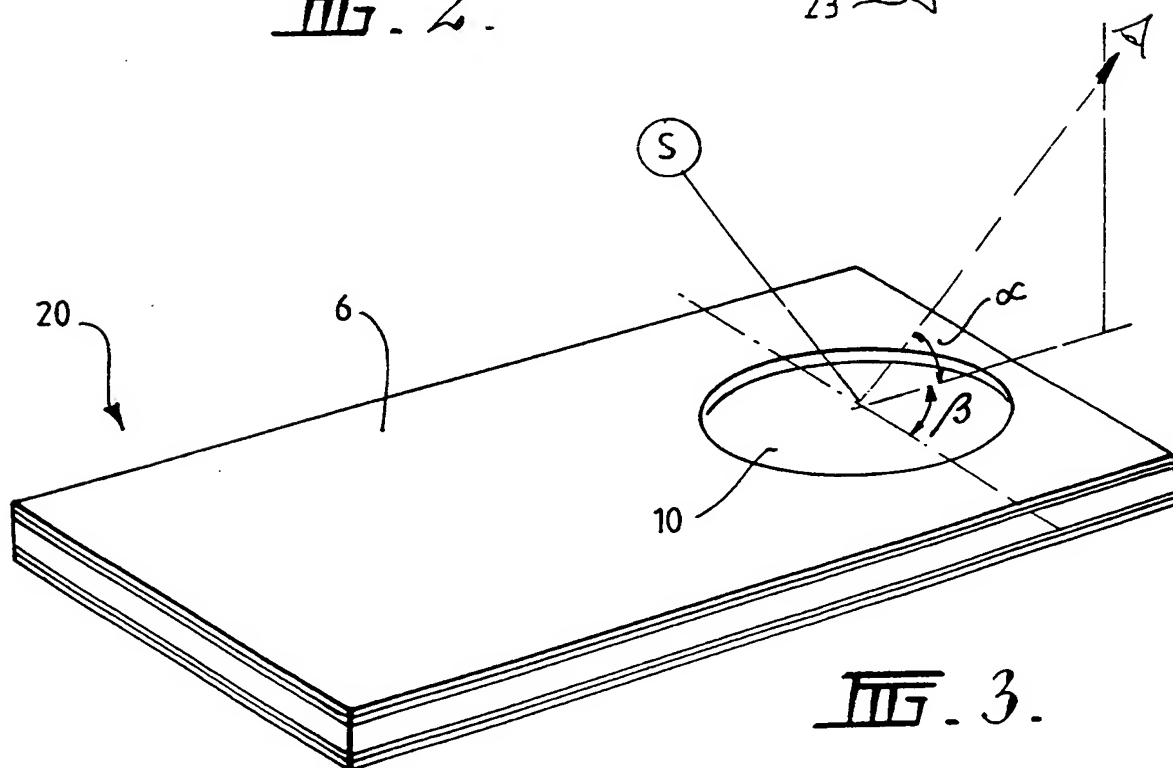
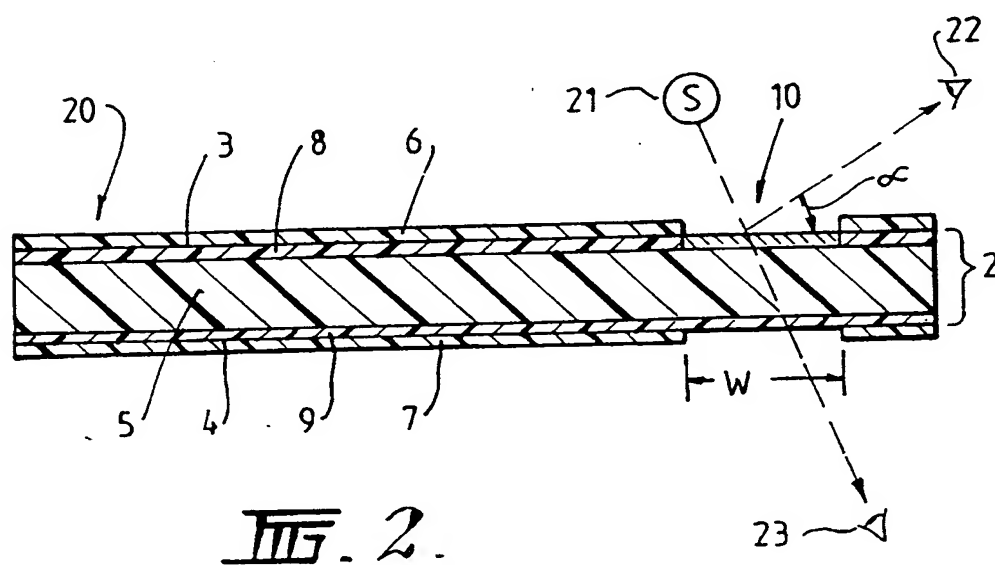
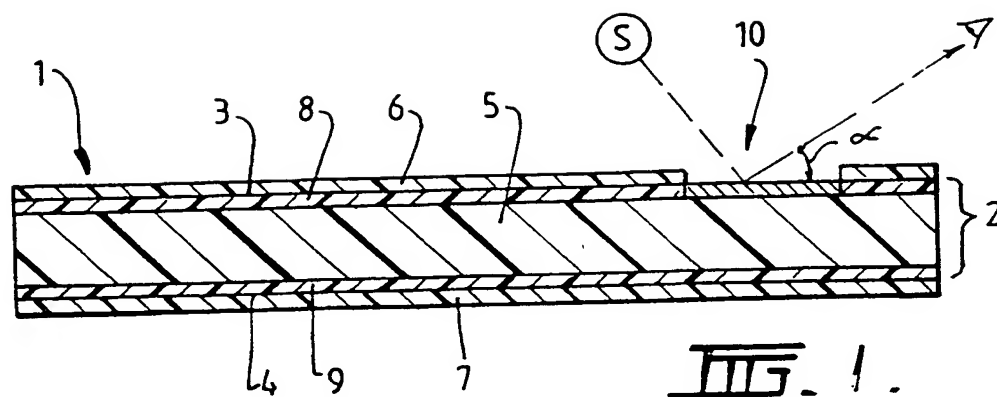
22. A method for producing a security feature according to any of claims 19 to 21, wherein the pores are formed by orienting the substrate so that its plane is at an angle to the beam of an energy source, exposing the substrate to the energy source beam such that pores are formed in an outer layer of the substrate, a longitudinal axis of the pores being substantially aligned with the direction of the energy source beam.

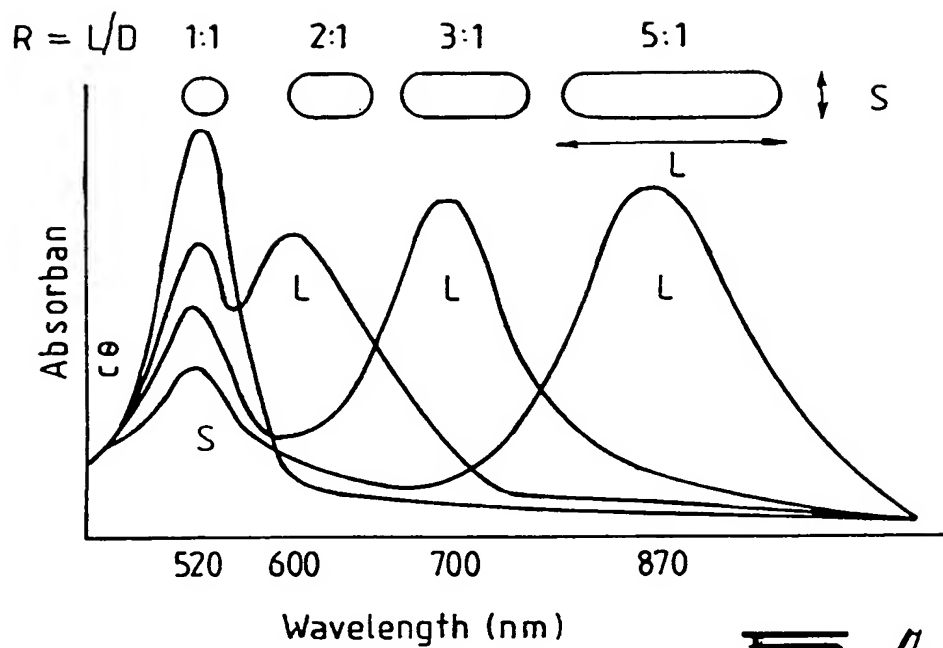
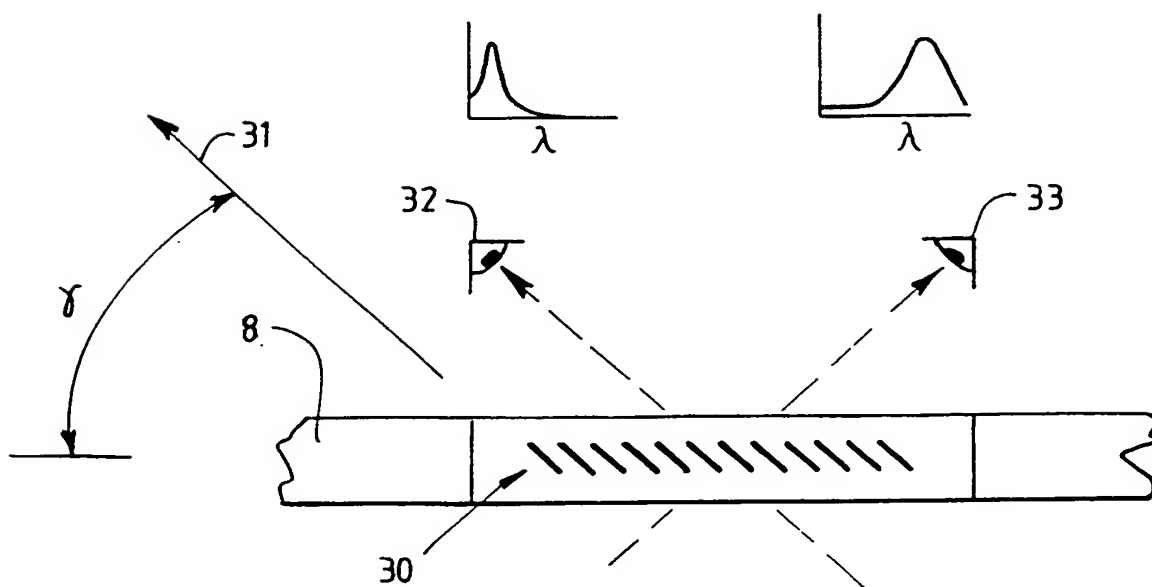
25

23. A method of producing a security document, comprising the steps of:

- (a) forming a sheet-like substrate,
- (b) placing particles for forming an authentication device on a transfer film,
- 30 the particles having at least a first dimension in the range of 1 to 200 nanometers, and
- (c) using the die to cause the transfer film to press the particles into the substrate.

24. A method of producing a security document according to claim 23, wherein the die is heated so that an outer layer of the substrate is melted to thereby facilitate the transfer of the particles from the transfer film into the substrate.
- 5 25. A method of producing a security document according to either of claims 23 or 24, wherein the die is an embossing die adapted to form a saw tooth or like profile in the surface of the substrate for positioning of the particles in the outer layer of the substrate, whereby the longitudinal access of the particles is at an angle to the plane of the security document.



FIG. 4.FIG. 5.

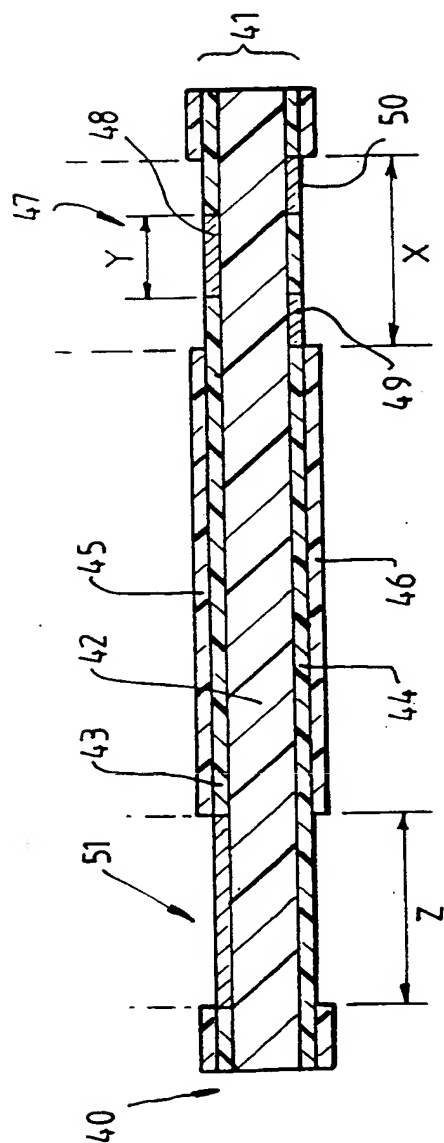


Fig. 6.

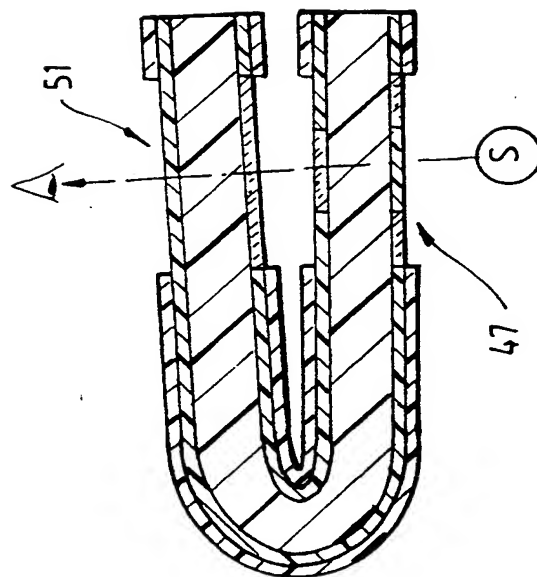
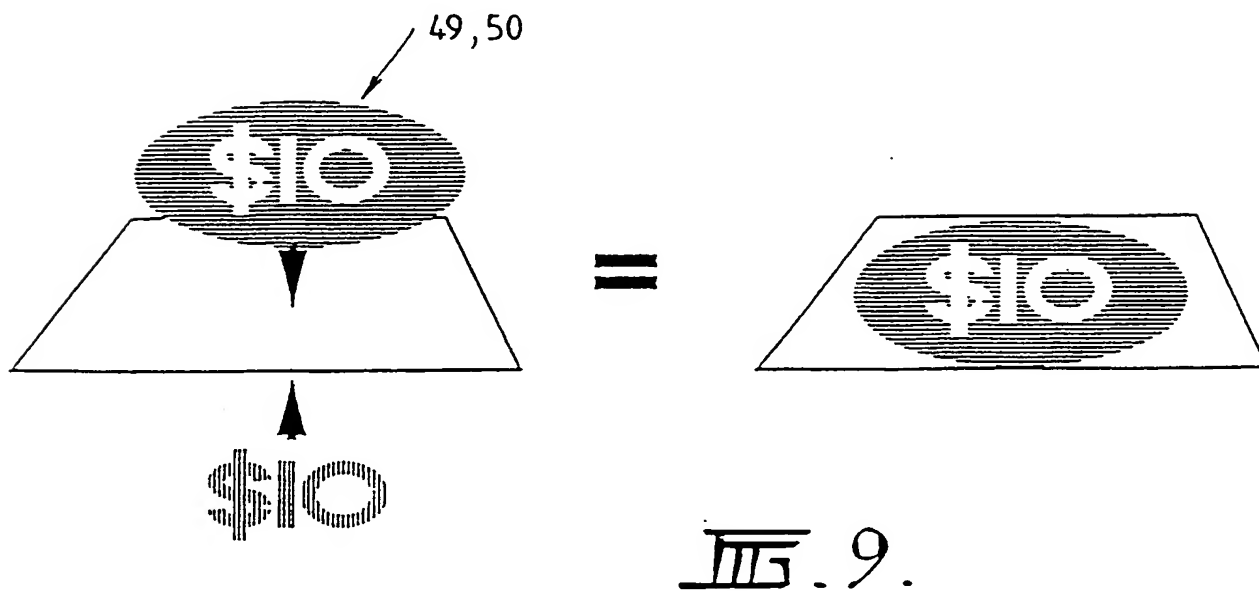
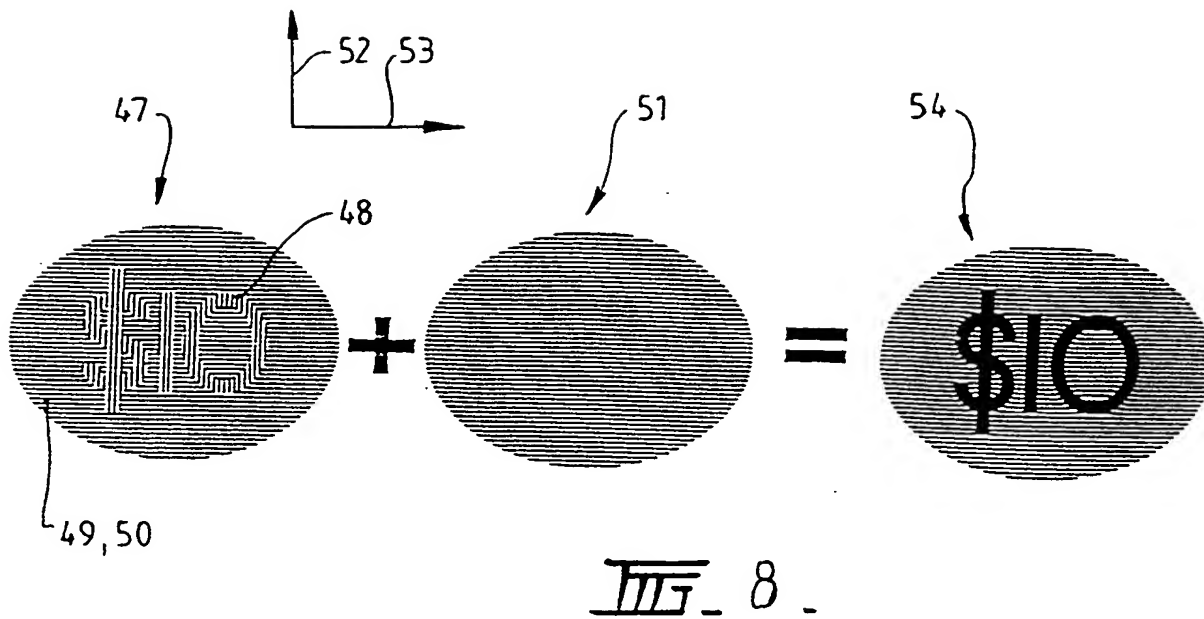


Fig. 7.



BEST AVAILABLE COPY

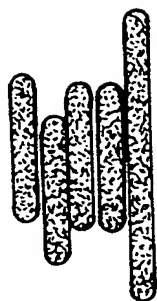


FIG. 10.

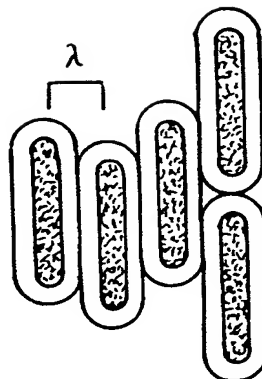


FIG. 11.

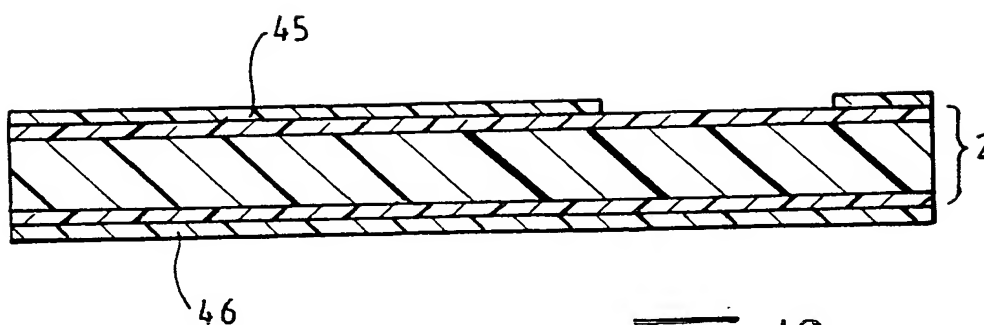


FIG. 12.

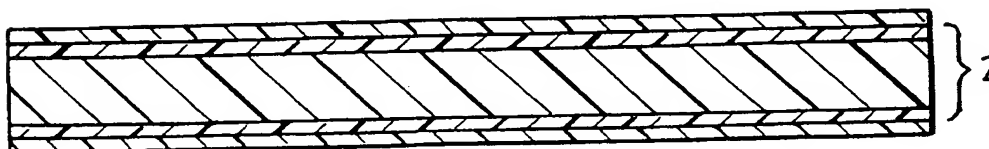
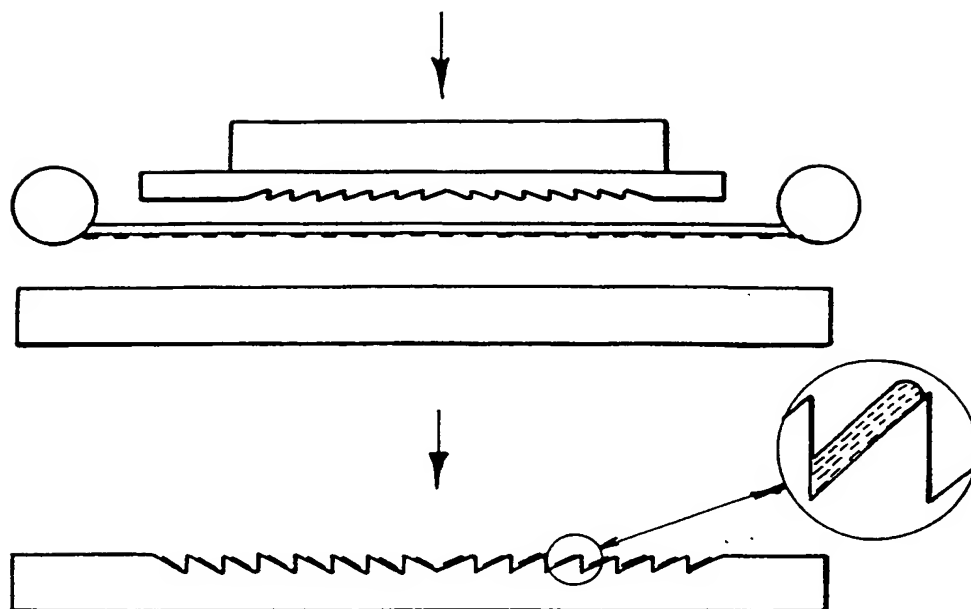
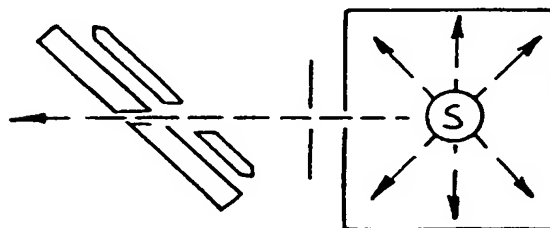


FIG. 13.



FIG. 14.FIG. 15.

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/AU 99/00830

## A. CLASSIFICATION OF SUBJECT MATTER

Int Cl<sup>6</sup>: B44F 1/12, B32B5/16, 31/12, B42D 15/10, 101:00, 209:00, 211:00, 217:00, 223:00, 225:00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC: B44F 1/IC, B32B5/IC, B42D15/IC, G01N 29/IC

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
WPAT: secur: or bank(w)note# or verif: or partic: and diameter or size or meter or metre or nano: or gran:

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5766764 A (OLLI et al.) 16 June 1998 see, in particular, col. 1, lines 66-67, and col.2, lines 22-26.	1-16
X	US 5733480 A (LEE) 31 March 1998 see, in particular, col. 4, lines 38-47.	1-16

☒ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" Document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 12 October 1999	Date of mailing of the international search report 18 OCT 1999
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (02) 6285 3929	Authorized officer  BARRY STEPHENS Telephone No.: (02) 6283 2106

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/AU 99/00830

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99/07502 A (KANSAS STATE UNIVERSITY RESEARCH FOUNDATION) 18 February 1999 see, in particular, the Abstract.	1-16
X	EP 0827137 A (DOWA MINING CO. LTD.) 4 March 1998 see, in particular, page 3, line 45.	1-16

# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/AU 99/00830

## Box I Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

## Box II Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. A security document as defined in claim 1
  2. A method of producing a security document as defined in claim 17.
  3. A method for producing a security feature as defined in claim 19.
  4. A method of producing a security document as defined in claim 23.
1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
  2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

## Information on patent family members

International application No.  
PCT/AU 99/00830

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
EP	827137	JP	10-069629
		US	5 902 676
END OF ANNEX			

**THIS PAGE BLANK (USPTO)**